Reprint, June, 1916.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 342

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

Washington, D. C. PROFESSIONAL PAPER January 8, 1916

THE PRESENT STATUS OF THE PASTEURIZATION OF MILK.

By S. HENRY AYERS, *Bacteriologist, Dairy Division.*

CONTENTS.

	Page.		Page.
Meaning of the term "pasteurization"	1	Supervision of the process	7
Value of pasteurization	1	Handling pasteurized milk	8
Extent of pasteurization in the United States	3	Cost of pasteurizing milk	9
Methods of pasteurization	4	Bacteria which survive pasteurization	9
Advantages of low-temperature pasteurization	5	Modern theories of pasteurization	13
Temperature and methods most suitable for pasteurization	6	The necessity for pasteurization	15
		References to literature	16

MEANING OF THE TERM "PASTEURIZATION."

The term "pasteurization," as applied to milk, should mean a process of heating to 145° F. and holding at that temperature for 30 minutes, but as applied under commercial conditions it is the process of heating for a short or long period, as the different methods demand, at temperatures usually between 140° and 185° F. The process is followed by rapid cooling. The term originated from the experiments of Louis Pasteur in France. From 1860 to 1864, in experimenting on the "diseases" of wine, he found that heating for a few moments at temperatures of from 122° to 140° F. was sufficient to prevent abnormal fermentations and souring in the wine. A little later he found that by a similar heating beer could be preserved from souring. The application of the process gave rise to the term "pasteurization."

VALUE OF PASTEURIZATION.

From a sanitary standpoint the value of pasteurization is of the greatest importance when market milk is under consideration. The

NOTE.—This bulletin will be of interest to health officers, medical men, scientific dairymen, and others who may be interested in the subject of pasteurization.

47267°—16

pasteurization of milk, when the process is properly performed, affords protection from pathogenic organisms. Such disease-producing bacteria as *Bacillus tuberculosis*, *B. typhi*, *B. diphtheriæ*, and the dysentery bacillus, when heated at 140° F. for 20 minutes or more, are destroyed, or at least lose their ability to produce disease.

According to Mohler (1),[1] pasteurization offers protection against foot-and-mouth disease. He makes the following statement: "Milk which has been pasteurized for the elimination of tubercle and typhoid bacilli will not prove capable of transmitting the disease [foot-and-mouth] to persons or animals fed with it." In view of the recent outbreak of foot-and-mouth disease in this country this is of importance.

Within recent years several epidemics of septic sore throat have been traced to milk. In some of these epidemics it was found possible by pasteurization to destroy streptococci which were isolated from throats of infected people and which were believed to be the infective agents. Pasteurization, properly performed, seems to protect against epidemics of this kind, but until the organism which causes the disease is definitely known it is impossible to say that it affords absolute protection.

Epidemics of scarlet fever have been traced to milk supplies, and in such cases pasteurization has been resorted to, with apparently satisfactory results, as a means of safeguarding the public health.

Pasteurization is of value from a commercial standpoint so far as it increases the keeping quality of the milk and prevents financial losses by souring. As practiced at the present time, commercial pasteurization, with reasonable care, destroys about 99 per cent of the bacteria, and while it does not prevent the ultimate souring of milk, it does delay the process. At the present time pasteurization is the best process for the destruction of bacteria in milk on a commercial scale. Many attempts have been made to destroy these bacteria by means of electricity, but its use commercially has not proved satisfactory. Its action is usually indirect, the bacteria being destroyed through the heat produced by the electric current or through chemical substances produced by decomposition of the milk. It is possible, however, that future research will develop some satisfactory method of treating milk in this manner.

The use of ultra-violet rays for the destruction of bacteria in milk has not proved to be of value as a commercial process. Experiments with these rays carried on by Ayers and Johnson (2) showed that while the rays cause great destruction of bacteria in milk, when exposed under suitable conditions, the process in its present state

[1] See references to literature at end of paper.

of development can not replace that of pasteurization on a commercial scale.

EXTENT OF PASTEURIZATION IN THE UNITED STATES.

Pasteurization, when first practiced by milk dealers in this country, was carried on secretly, and, except as a means of preserving the milk, was regarded by them as a process of no value. As the practice became more general the subject of pasteurization was studied, and its value as a means of destroying disease-producing bacteria was recognized. In consequence of the recognition of the merits of the process there has been during the last 10 years a rapid increase in the quantity of milk pasteurized, particularly in the larger cities. Jordan (3) states that 10 years ago only about 5 per cent of the milk supply of New York City was pasteurized, as compared with about 40 per cent in 1912 and 88 per cent in 1914. In Boston, in 1902, very little milk was pasteurized, while at present 80 per cent is so treated, and in many of the smaller cities there have been corresponding increases in the quantity of milk pasteurized during the last few years.

The general tendency in this country to-day is toward the pasteurization of all market milk, with the exception of certified and inspected milk from tuberculin-tested herds. Some idea of the extent of pasteurization may be gained from Table I. The figures[1] were supplied by the milk-investigations section of the Dairy Division and were obtained from replies to circular letters sent to health officers.

Table I.—*Extent of pasteurization of milk in cities in the United States.*

Population of cities.	Number of cities answering question.	More than 50 per cent pasteurized.	11 to 50 per cent pasteurized.	0 to 10 per cent pasteurized.	None pasteurized.
More than 500,000	9	7	2	0	0
100,001 to 500,000	40	12	20	6	2
75,001 to 100,000	19	5	8	4	2
50,001 to 75,000	30	4	15	6	5
25,001 to 50,000	78	13	31	12	22
10,001 to 25,000	168	10	40	18	100
Total	344	51	116	46	131

It will be seen that of nine cities with a population of more than 500,000 each, in seven more than 50 per cent of the milk is pasteurized; in fact, the proportion is much higher, as Table II shows. Since these figures were obtained the per cent of milk pasteurized has probably increased in these cities.

[1] These figures were obtained through the kindness of Mr. Ernest Kelly and Mr. L. B. Cook.

TABLE II.—*Proportion of total milk supply pasteurized in certain cities.*[1]

City.	Per cent pasteurized.	City.	Per cent pasteurized.
Boston, Mass	80	Philadelphia, Pa	85
Chicago, Ill	80	Pittsburgh, Pa	95
Detroit, Mich	57	St. Louis, Mo	70
New York, N. Y	88		

[1] In the small cities the per cent of milk pasteurized is much lower.

METHODS OF PASTEURIZATION.

At present there are three processes of pasteurization practiced in this country. The first is known as the flash, or continuous, process; the second, the holder, or holding, process; and the third is known as pasteurization in the bottle.

The flash process consists in heating rapidly to the pasteurizing temperature, then cooling quickly. In this process the milk is heated from 30 seconds to 1 minute only, usually at a temperature of 160° F. or above.

In the holder process the milk is heated rapidly to temperatures of from 140° to 150° F. and held for approximately 30 minutes, after which it is rapidly cooled. Sometimes the milk, instead of being held at a certain temperature in one tank for 30 minutes, is merely retarded in its passage through several tanks so that the length of time is required for the milk to pass through. In such cases, however, there is no assurance that all the milk is held for the desired time. The holder process, which is gradually replacing the flash process, is more effective and is superior in every way.

Pasteurization in bottles is the latest development of the process to be used on a practical scale. This process, as first practiced, consisted in putting the raw milk into bottles with water-tight seal caps, then immersing them in hot water until heated to 145° F. and holding them at that temperature for 20 or 30 minutes. The cooling was accomplished by gradually lowering the temperature of the water until that of the milk reached 50° F. This method is now in use in several milk plants. The advantage of this process is in the fact that the milk after heating is not exposed until it reaches the consumer, thereby eliminating any danger of reinfection with disease-producing organisms through handling. For this process to be successful it is necessary, of course, that the seals be absolutely water-tight, as the bottles are submerged in water, and, during cooling, a defective cap might allow infection by polluted cooling water. The disadvantage of this process is in the increased cost of pasteurization, caused by the cost of the seal caps. It is claimed, however, that the saving in milk losses by pasteurization in bottles makes up

for the added expense of caps. It is now possible to pasteurize milk in this manner without using water-tight caps. This is accomplished by the aid of devices which fit over the tops and necks of the bottles, thereby protecting the ordinary paper caps from the water which is sprayed on the bottles for the purpose of heating or cooling. This method of protecting the tops permits the use of the ordinary caps and removes the possible danger of polluted water infecting the milk.

Another method of pasteurization, or, rather, a modification of the present holder process, is that of bottling hot pasteurized milk. Work on this process was begun in 1911, and the process was first suggested by the author (4) in 1912; further work on this subject may be found in an article published in 1914 (5). The process consists in pasteurizing milk by the holder method at 145° F. for 30 minutes, then bottling, while hot, in hot, steamed bottles. The bottles are steamed for two minutes immediately before filling. After filling with hot milk and capping with ordinary caps the bottles may be cooled at once by any of the systems in which the caps are protected and the bottles sprayed with water, or the forced cold-air circulation may be used.

The use of forced-air circulation for cooling milk is entirely new, and while only suggested in the paper describing the process of bottling hot pasteurized milk, recent experiments with it for cooling indicate that it is practicable. We have obtained bacteriological results which show that this process is always as good as, and often superior to, the process of pasteurization in bottles. The results of these experiments are being prepared for publication. While working on this process of bottling milk hot it was found that a similar process was patented several years ago. It was described by De Schweinitz (6), and recently two other patents on the process have appeared.

ADVANTAGES OF LOW-TEMPERATURE PASTEURIZATION.

In general the trend of pasteurization is toward the holder process, and with this tendency the use of lower temperatures is becoming more common. As a general rule, when the holder process is used milk is heated to 145° F. for 20 or 30 minutes and to at least 160° F. for 1 minute when the flash process is used. From bacteriological, chemical, and economical standpoints it is highly desirable that milk be pasteurized at low temperatures.

From a bacteriological standpoint, pasteurization at 145° F. for 30 minutes gives assurance, so far as we know, of a complete destruction of disease-producing bacteria, and at the same time leaves in the pasteurized milk the maximum percentage of the bacteria that cause milk to sour (lactic-acid bacteria) and only a small percentage of

those that cause it to rot (peptonizers). When higher temperatures are used, while the total number of all kinds of bacteria is reduced, the percentage of lactic-acid bacteria becomes less and less and the peptonizing group increases until at 180° F., or above, when the lactic-acid bacteria are practically destroyed and the most of the bacteria left belong to the peptonizing group. The heat-resistant lactic-acid bacteria which survive pasteurization at 145° F. for 30 minutes play an important rôle in the souring of commercially pasteurized milk.

From a chemical standpoint the advantage of low temperatures is in the fact that milk pasteurized at 145° F. for 30 minutes does not undergo any appreciable change which should affect its nutritive value or digestibility. According to Rupp (7) the soluble phosphates of lime and magnesia do not become insoluble, and the albumin does not coagulate. At 150° F. about 5 per cent of the albumin is rendered insoluble, and the amount increases with higher temperatures to 160° F., when about 30 per cent of the albumin is coagulated. The heating period in Rupp's experiments was 30 minutes.

From an economic standpoint the advantage of pasteurization at low temperatures is in the saving in the cost of heating and cooling the milk. Bowen (8) has shown that the flash process of pasteurization requires approximately 17 per cent more heat than the holder process. There is, of course, a correspondingly wider range through which the milk must be cooled, which also adds to the cost of pasteurizing. This is owing to the fact that in the holder process milk may be heated to 145° F. and held for 30 minutes, while to obtain the same bacteriological efficiency with the flash process, with one-minute heating, the milk would have to be heated to 165° F.

TEMPERATURES AND METHODS MOST SUITABLE FOR PASTEURIZATION.

In view of the advantages of low-temperature pasteurization, it is advisable to pasteurize milk at 145° F. for 30 minutes. It has been found that heating at 140° F. for that length of time will destroy pathogenic bacteria, but in practice it is advisable to use a temperature several degrees above the limit of safety. During extensive studies of the effect of different temperatures it has been shown that an increase of 5 degrees above 140° F. produces a great increase in the destruction of bacteria in milk.

The holder process, as previously described, is entirely satisfactory when properly used. Considerable attention is necessary, however, to see that the milk is not contaminated during cooling and capping.

Pasteurization in bottles eliminates the danger of reinfection, provided no water is introduced into the bottles during cooling.

From a sanitary standpoint this process is very satisfactory. In the past, on account of the difficulty of treating large quantities of milk, pasteurization in bottles has not been used to any great extent in large plants.

The bottling of hot pasteurized milk in steamed bottles is a process which eliminates the danger of reinfection and can easily be adapted to the treatment of milk in large quantities.

Any one of these methods of pasteurization is satisfactory, provided a temperature of 145° F. is maintained for 30 minutes and reinfection is prevented during subsequent handling of the milk.

SUPERVISION OF THE PROCESS OF PASTEURIZATION.

As is the case with almost every known process which permits of variation by the operators, the process of pasteurization is frequently performed improperly. This is attributable sometimes to lack of care on the part of the operators, but probably more often to lack of proper knowledge of the functions of the process. Pasteurization calls for supervision by competent inspectors to remedy such conditions, and supervision is provided for in only a few of the larger cities. In these cities the process must be performed by machines approved by the boards of health, and at such temperatures and for such periods of holding as are required.

In some cities pasteurized milk must be marked "Pasteurized," and in some cases the temperature must be stated, together with the date of pasteurization.

In most of our cities there is a great lack of proper control over the process of pasteurization, and a standard method of pasteurization and definite procedure for proper supervision of the process is greatly needed.

The process of pasteurization is by no means "foolproof." It demands a knowledge on the part of the operator of the action of the process and its objects. Not all operators have such knowledge. Records obtained in 1912 from 231 milk plants showed that 99 per cent of those which used the holder process pasteurized at the proper temperature. Among those which used the flash process only 57 per cent employed temperatures high enough to give satisfactory results, while in the other 43 per cent the temperatures were too low to be effective in the destruction of pathogenic bacteria. At the present time this condition is much improved.

Anyone who has had the opportunity to examine the numerous plants where pasteurization is practiced has undoubtedly found cases in which as many bacteria were introduced in cooling and bottling as were destroyed by the heating process. It is in such cases that the operator's ignorance of the fundamental principles of the process is

most strikingly shown. One false step, such as running pasteurized milk through a piece of dirty cheesecloth before it enters the bottle filler, may undo all the previous work. Pasteurization is an added expense, and merely as a matter of business, it is hard to believe that after the process is properly performed anyone would willfully allow the results to be spoiled by a single operation, no matter whether the object of the process is to produce a sanitary milk or merely to preserve it. The failure of a few plants to pasteurize properly is no reason for condemning the process. In such cases a little education will often produce marked improvement and enable the milk dealer to meet city regulations.

The control of the process of pasteurization should be based only on accurate scientific data. In the past it has often been the practice to expect a bacterial reduction of 99 per cent during pasteurization. While it is an easy matter to destroy 99 per cent of the bacteria when the raw milk contains large numbers, it is often impossible, on account of heat-resistant bacteria which are not necessarily spore formers, to destroy 99 per cent when the milk contains about 100,000 bacteria per cubic centimeter. In a large number of experiments in which milk was pasteurized under exact laboratory conditions, where no reinfection was possible, in one sample only 17 per cent of the bacteria were destroyed. Often 99 per cent of the bacteria may be destroyed, and yet the milk may still contain hundreds of thousands, while in other cases in which it contains only tens of thousands, the per cent of reduction may have been only from 80 to 90. The efficiency of the process can not be based on the per cent of bacteria destroyed.

In the control of pasteurization it is essential that the proper temperature be used and that the process be so performed that no reinfection takes place. This can be accomplished best by direct supervision of milk plants by trained men who have authority to carry on such supervision, and by bacteriological control of the process.

HANDLING PASTEURIZED MILK.

The pasteurization of milk destroys about 99 per cent of the bacteria; consequently the milk is not sterile. On account of this fact pasteurized milk is still a perishable product, and must be handled with the same care as raw milk. This is a point for both the consumer and the milkman to remember.

Milk after pasteurization should be cooled to about 40° F. and kept at that temperature until delivery. During warm weather it should be iced on the delivery wagons. From a sanitary standpoint all milk, whether raw or pasteurized, should be delivered as soon as possible, in order that the consumer may get it in the best condition.

In the best pasteurized milk, when held at about 40° F., there is only a slight bacterial increase during the first 24 hours. In many cases the pasteurization and delivery may be so arranged that the consumer gets the milk before much, if any, change has taken place in the bacterial content. The tops of the bottles should have overlapping caps to protect them from dust, dirt, or other contamination, and the cap should be marked "Pasteurized" and show the date and the temperature at which the milk was treated. For the benefit of the consumer this information should be printed on the cap, as it is only right for him to know whether he is using raw or pasteurized milk, and if pasteurized, the temperature may be of importance to him. Some people object to pasteurized milk, especially for infant feeding, while others desire it. It has been the experience of numerous milk dealers that the labeling of their product has greatly increased their trade.

COST OF PASTEURIZING MILK.

The cost of pasteurizing milk is a matter of considerable importance. It has been found by Bowen (loc. cit.) that the average cost of pasteurizing 1 gallon of milk is a little more than three-tenths of a cent ($0.00313). He obtained this information from a series of tests in five establishments which were considered to represent the average city milk plant. The pasteurizing equipment in each consisted of a heater, a holding tank, a regenerator, and a cooler. The cost of the operation was based on the pasteurizing cycle, starting with the initial temperature of the raw milk and raising it to the pasteurizing temperature, then cooling to the initial temperature of the raw milk. He based the costs on daily interest at 6 per cent per annum on capital invested in pasteurizing equipment, and depreciation and repairs per day at 25 per cent per annum, interest per day at 6 per cent per annum on capital invested in mechanical equipment for pasteurizing, and depreciation and repairs per day at 10 per cent per annum. Other costs figured were labor, coal at $4 a ton, cooling water at 50 cents a thousand cubic feet, and refrigeration at $1 a ton.

BACTERIA WHICH SURVIVE PASTEURIZATION.

Earlier in this paper it is stated that about 99 per cent of the bacteria in milk are destroyed by pasteurization; consequently about 1 per cent of the bacteria remain alive in the milk, and that just what kinds are left depends entirely on the temperature to which the milk is heated. From studies of the bacteria which survive pasteurization (9) it is possible to show graphically the hypothetical relations of the bacterial groups in raw milk and in milk pasteurized by the holder process at various temperatures under laboratory conditions.

The bacterial flora of the various kinds of milk is represented in figure 1 by columns of equal length divided into sections, which, in a general way, show the relative proportion of the bacterial groups.

From the figure it may be seen that raw milk contains four principal groups of bacteria—the acid, inert, alkali, and peptonizing

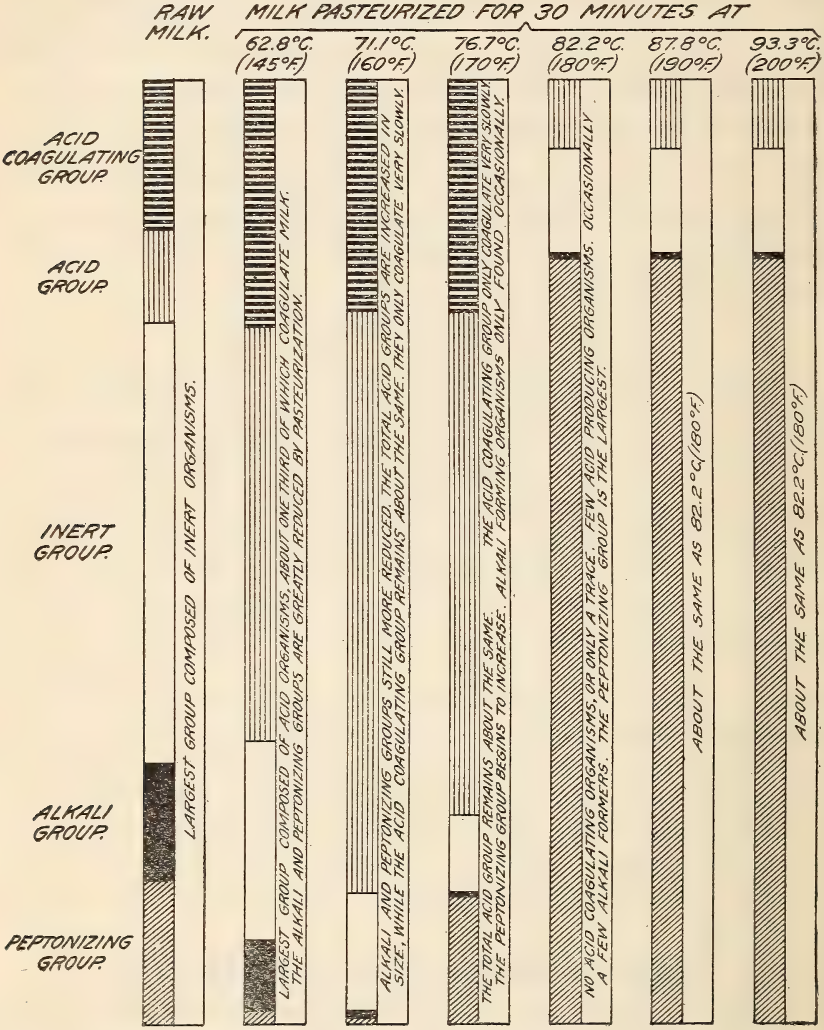

FIG. 1.—The hypothetical relation of the bacterial group to raw and pasteurized milk.

groups. The acid group is divided again into two, the acid-coagulating, which coagulates milk within 14 days, and the acid group, which merely produces acid and does not coagulate it in less time than that. In raw milk the inert group is the largest.

In milk pasteurized at 145° F. the great increase in the proportion of the acid-coagulating and acid groups is plainly shown. The per cent of the alkali and peptonizing groups is reduced. At 160° F. the total-acid group is still the largest, but the acid-coagulating group is made up of bacteria which coagulate very slowly. At this temperature the alkali group is greatly reduced, and the peptonizing reduced to the minimum. At 170° F. the total-acid group remains about the same, but the organisms produce acid and coagulate the milk very slowly. The alkali group is practically destroyed, although occasionally a sample may show a fairly high per cent. The most important change is in the peptonizing group. At this temperature the ratio of this group to the total number of bacteria begins to increase. The increase when milk is pasteurized at 180° F. is even more striking. At this temperature more than 75 per cent of the bacteria which survive are peptonizers. No organisms of the acid-coagulating group are found, and only a small per cent of the acid group. Occasionally a few of the alkali group may be found. At 190° F. and 200° F. the bacterial groups which survive are about the same in their relative sizes as at 180° F.

It is very evident that when the bacterial flora of pasteurized milk is under discussion the temperature of the process is of fundamental importance. From figure 1 the bacterial groups left in milk pasteurized at different temperatures may be seen at a glance. It must be remembered, however, that the relations of the bacterial groups represent only average conditions and that the bacterial flora of every sample of milk must not be expected to conform exactly to these averages. Variations in methods and conditions in the production of milk may considerably influence the bacterial group relations of an individual sample.

The results in figure 1 may perhaps be better explained in popular terms. When milk is pasteurized at 145° F. for 30 minutes, the most of the bacteria (lactic-acid bacteria) left alive in it are of the kind which causes it to sour, and there are present only a few bacteria (peptonizing) which cause it to rot. As the milk stands, the acid formers grow and cause the milk to sour instead of rot. When milk is pasteurized at 180° F. for 30 minutes, however, the bacteria (lactic-acid) which cause the souring of milk are practically all destroyed, and those which are alive (peptonizing) continue to grow and cause the milk to rot.

Since the general groups of bacteria which survive pasteurization have been discussed, let us now consider a more specific group. It has been the custom of some authorities to consider the presence of streptococci in pasteurized milk an indication of an ineffective process. In a recent study (10) of the subject, however, it was

found that certain strains of steptococci are able to survive pasteurizing temperatures.

The thermal death points of 139 cultures of streptococci isolated from cow feces, from the udder and mouth, and from milk and cream, showed a wide variation when the milk was heated for 30 minutes under conditions similar to pasteurization. At 140° F., the lowest pasteurizing temperature, 89 cultures, or 64.03 per cent, survived; at 145° F., the usual temperature for pasteurizing, 46, or 33.07 per cent, survived; and at 160° F., 2.58 per cent survived; all these were destroyed at 165° F. The streptococci from the udder were, on the whole, less resistant, and those from milk and cream more resistant to heat than those from the mouth and feces of the cow.

Two classes of streptococci seem to survive pasteurization: (1) Streptococci which have a low majority thermal death point: (the temperature at which a majority of the bacteria are killed), but among which a few cells are able to survive the pasteurizing temperature. This ability of a few bacteria may be owing to certain resistant characteristics peculiar to them or may be caused by some protective influence in the milk. (2) Streptococci which have a high majority thermal death point, and which, when such is the case, survive because this point is above the temperature of pasteurization. This ability to resist destruction by heating is a permanent characteristic of certain strains of streptococci.

It is evident that certain varieties of streptococci are able to survive pasteurization, while others are probably always destroyed. Numerous investigators have studied the thermal death point of streptococci isolated from patients having septic sore throat and have found that the organism was destroyed by pasteurization at 145° for 20 minutes. These results, together with the protection which proper pasteurization seems to afford against epidemics of that disease caused by milk supplies, indicate that the varieties of streptococci associated with or responsible for the disease are among the varieties which have a low thermal death point.

In a similar study (11) of the ability of colon bacilli to survive pasteurization it was found that certain strains could survive pasteurization at 145° F. for 30 minutes. On examining 174 cultures of colon bacilli it was found that at 140° F., the lowest pasteurizing temperature, 95 cultures survived; at 145° F., the usual temperature for pasteurization, 12 survived. In each case the heating period was 30 minutes. Considerable variation was observed in the thermal death point of the colon bacilli which survived at 145° F. When the cultures which withstood the first heating were again heated it was found that many did not survive, and in each subsequent heating different results were obtained. Colon bacilli have a low majority

thermal death point and, on account of the survival of a few cells, survive the pasteurizing process.

The colon test as an index of the efficiency of the process of pasteurization is complicated by the ability of certain strains to survive a temperature of 145° F. for 30 minutes and to develop rapidly when the pasteurized milk is held under certain temperature conditions which might be met during storage and delivery. Consequently the presence of a few colon bacilli in pasteurized milk under ordinary market conditions does not necessarily indicate that the milk was not properly heated. The presence of a large number of colon bacilli immediately after the heating process may, however, indicate improper treatment of the milk.

If milk is pasteurized at a temperature of 150° F. or above for 30 minutes, it is not to be expected that any colon bacilli will survive; consequently under such conditions the colon test for the effectiveness of pasteurization may be of value. It must be remembered, however, that a study of more cultures may reveal strains of colon bacilli that are able to survive this or even a higher temperature.

MODERN THEORIES OF PASTEURIZATION.

Pasteurization at present is looked upon with favor by medical men, sanitarians, dairymen, and consumers, but the art has not been developed without opposition, and even now its value is not universally accepted. Most of the objections to pasteurized milk have been based on theory or on experiments in which the milk was pasteurized at high temperatures and in view of our modern theories are of no great importance.

One of the greatest objections to pasteurized milk has been that the heating destroyed the lactic-acid bacteria and that putrefactive organisms were left, which, when relieved from the restraining action of the acid-forming bacteria, would develop, forming toxins and putrefactive products (12). It was believed that the milk, because it was not sour, would be consumed in that condition. This objection was based on experiments in which milk was heated to temperatures near the boiling point and can not be applied to milk pasteurized at low temperatures. From the results of seven years' work in the Dairy Division on commercial pasteurized milk it has been found that such milk sours, as raw milk does, but that the souring is delayed. Pasteurization for 30 minutes at temperatures of about 145° F., as is generally practiced in this country, does not destroy all the lactic-acid organisms, and those which survive play an important rôle in the souring of commercially pasteurized milk.

Another objection to pasteurized milk has been that bacteria grow faster in it than in raw milk. In spite of several experiments which

seem to prove this point, it has never been thoroughly established. It has been found that the rate of bacterial increase is approximately the same when the comparison is made between raw milk and pasteurized milk having about the same bacterial content.

It is often stated that pasteurization, even if it does destroy bacteria, does not destroy poisonous products of their growth. This can hardly be considered a real objection, for if they are present in raw milk they must be consumed with it, and if pasteurization does not destroy them the pasteurized milk would be no worse than the raw milk.

The question as to whether pasteurization destroys beneficial enzyms is still an open one. In the light of our present knowledge of the enzyms in milk and the part they play in the digestive process it is quite impossible to settle the question of their importance. It is evident, however, that the low temperatures now in use in pasteurization have little effect on the commonly recognized enzyms.

The opponents of pasteurization have raised an objection on the ground of its direct influence on the milk producer. It has been asserted that pasteurization would cause lax methods of production on the farm, for the reason that farmers would know that the milk was to be pasteurized and, therefore, they could be careless in its production. There seems to be some basis for this objection, but in any city where there is any inspection of the raw-milk supply the same inspection can and should be continued even though the milk is to be pasteurized.

From a chemical standpoint serious objections have been raised against pasteurized milk, because the heating produces changes which render the milk less digestible, particularly in the case of infants. As has already been stated, however, Rupp has found that milk pasteurized at 145° F. for 30 minutes does not undergo any appreciable chemical change. He found that soluble phosphates do not become insoluble, that the albumin does not coagulate, and that when higher temperatures are used chemical changes do occur. He also developed the fact that 5 per cent of the albumin is rendered insoluble in milk heated for 30 minutes at 150° F., while at 160° F. 30.78 per cent of the albumin is coagulated. According to Hess (14), however, milk pasteurized 30 minutes at 145° F. may cause, in infants, a mild form of scurvy, which yields readily to such a simple remedy as orange juice.

Further evidences that low-temperature pasteurization does not injure the digestibility and nutritive value of the milk is shown by the results of feeding experiments on babies. According to Weld (13) a number of babies that were fed raw milk and pasteurized milk showed only a slight difference in the average net daily gain in weight during the feeding period. The slight difference was in favor of pasteurized milk.

High-temperature pasteurization of earlier days must not be confused with low-temperature pasteurization of the present day. Many of the objections which have been raised to pasteurization have been founded on the observation of milk heated to high temperatures. Unfortunately, not until recently has the use of low temperatures entirely changed our views in regard to the value of pasteurization. The fallacy of the objections to pasteurization has been shown, however, through scientific research in the past few years, and as a result the value of the process has been firmly established.

THE NECESSITY FOR PASTEURIZATION.

Although pasteurization is being more extensively practiced in most cities, particularly the larger ones, there are health departments in some of the smaller cities which are strongly opposed to the process; there are also many people who object to it. The problem of pasteurization is not based simply on the question of which is preferable, raw or pasteurized milk, but rather upon the most economical and practical way of producing a safe milk supply. In small cities where money enough is available to pay for inspection, and where the milk supply is drawn from farms within a short distance of the city, it may be feasible, without pasteurization, to bring the supply to a point of reasonable safety. To produce, however, the same degree of safety in the supply of a large city by inspection would involve a tremendous expense.

Let us consider for a moment the supply of New York City, which in 1912 amounted to about 2,500,000 quarts daily. This milk came from 44,000 farms in six States, and was the product of about 350,000 cows. Some of it had to be transported 400 miles or even more. It was estimated that 127,000 people were engaged daily in handling the milk supply of that city. It is hardly necessary to discuss the magnitude of a system of inspection suitable to guarantee a safe milk supply of this size.

There is, of course, in the large cities a small quantity of high-grade raw milk, but it is produced under special conditions and sells at a higher price than regular milk. The cost of such milk makes it prohibitive for use in poor families. The means of creating a safe milk supply for general consumption, especially for large cities, is, then, in inspection, developed to the highest practical degree, followed by proper pasteurization.

It seems probable that within the next few years a large proportion of the milk supply in American cities will be pasteurized. This condition will come first in the larger cities, where the safeguarding of the milk supply is a more difficult problem. For economic reasons, and in recognition of the process as a means of eliminating

certain risks which can not be completely eliminated in any other way, the pasteurization of milk is certain to be the general practice in this country.

The greatest feature of the process of pasteurization, properly performed, is that while no valid objections can be raised against the process, it causes an additional degree of safety in milk produced and handled even under the most effective system of inspection.

REFERENCES TO LITERATURE.

1. Mohler, John R. Conditions and diseases of the cow injuriously affecting the milk. Treasury Department, Hygienic Laboratory Bulletin 56, pp. 501–526. 1909.
2. Ayers, S. Henry, and Johnson, W. T., jr. The destruction of bacteria in milk by ultra-violet rays. Centralblatt für Bakteriologie, Parasitenkunde u. Infektionskrankheiten. Zweite Abteilung, vol. 40, no. 1/8, pp. 109–131. Jena, Feb. 16, 1914.
3. Jordan, Edwin O. The municipal regulation of milk supply. Journal of the American Medical Association, vol. 61, no. 26, pp. 2286–2291. Chicago, Dec. 27, 1913.
4. Ayers, S. Henry. The pasteurization of milk. U. S. Department of Agriculture, Bureau of Animal Industry Circular 184, 44 p., 32 figs. 1912.
5. Ayers, S. Henry, and Johnson, W. T., jr. Pasteurization in bottles and the process of bottling hot pasteurized milk. Journal of Infectious Diseases, vol. 14, no. 2, pp. 217–241. Chicago, March, 1914. Also U. S. Dept. of Agriculture Bul. 240.
6. de Schweinitz, E. A. The pasteurization and sterilization of milk. Yearbook of the U. S. Department of Agriculture, 1894, pp. 331–356.
7. Rupp, Philip. Chemical changes produced in cows' milk by pasteurization. U. S. Department of Agriculture, Bureau of Animal Industry Bulletin 166, 15 p. 1913.
8. Bowen, John T. The cost of pasteurizing milk and cream. U. S. Department of Agriculture Bulletin 85, 12 p. 1914.
9. Ayers, S. Henry, and Johnson, W. T., jr. A study of the bacteria which survive pasteurization. U. S. Department of Agriculture, Bureau of Animal Industry Bulletin 161, 66 p. 30 figs. 1913.
10. Ayers, S. Henry, and Johnson, W .T., jr. Ability of streptococci to survive pasteurization. Journal of Agricultural Research, vol. 2, no. 4, pp. 321–330. July 15, 1914.
11. Ayers, S. Henry, and Johnson, W. T., jr. Ability of colon bacilli to survive pasteurization. Journal of Agricultural Research, vol. 3, no. 5, pp. 401–410. Feb. 15, 1915.
12. Ayers, S. Henry, and Johnson, W. T., jr. The bacteriology of commercially pasteurized and raw market milk. U. S. Department of Agriculture, Bureau of Animal Industry Bulletin 126, 98 p. 1910.
13. Weld, Ivan C. George M. Oyster, jr., Baby Milk Philanthropy, report for the first 18 months beginning Apr. 24, 1911, and ending Oct. 24, 1912. 20 p.
14. Hess, Alfred F. Infantile scurvy. II. A new aspect of symptomatology, pathology, and diet. Journal of the American Medical Association, vol. 65, p. 1003–1006. Sept. 18, 1915.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1916